

A POSSIBLE SCENARIO FOR FUTURE
PETROLEUM DEVELOPMENT
IN THE WESTERN ARCTIC

James M. Shearer

EVIDENCE PRESENTED
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Now that petroleum development has begun in the Western Arctic it is not a futile exercise to attempt to predict the nature of this development in future years. I will do this in two stages, beginning with the development and activities to date followed by an estimate of future exploration activities and their ramifications in terms of future hydrocarbon production and delivery to southern markets.

In Figure 1, the shaded area shows those areas, from a geological point of view, which have even the smallest potential for oil and gas (sedimentary basins).

Figure 2 shows the leasing arrangement to date, from Oilweek, in the Mackenzie Delta-Beaufort Sea region. It should be noticed that leasing covers the whole continental shelf of the Beaufort Sea out to and even beyond the 200 metre water depth line.

Among the rocks that may contain oil and gas, those of the Mesozoic and Tertiary periods, because of higher organic productivity during those times, generally contain larger amounts of hydrocarbons than older, middle and upper paleozoic rocks. Figure 3, then, outlines the edges of the Tertiary and Cretaceous Basin rocks which are thought to be the most highly petroliferous. The northern edge of this

basin is drawn along the 200 metre contour line, as this depth is thought to be the outer limit in terms of possible exploration drilling. This 200 metre limit in fact coincides with the continental slope where the depth, as one moves northwestward from the shelf, drops from some 80 metres to 400 metres of water very quickly.

The drilling record to date is shown in Figure 4, with no mention of the ancillary roads, seismic lines and camps which were necessary in obtaining these 90 onshore wells and 10 wells from artificial islands. Most of these supporting activities and facilities are not permanent features, although some have caused permanent damage to the landscape. In contrast to this are the relatively permanent facilities to be constructed for the eventual processing and transport of oil and gas.

Figure 5 shows the gas plants, feeder lines and gas trunk lines which are proposed, at this point, as viable delivery systems to bring these discovered petroleum resources to market. This map shows both Canadian Arctic Gas alternatives; the route west of Aklavik and the Cross Delta Route. The Foothills proposal coincides with the Delta lateral of the West Delta trunk line proposal of CAGPL. It is the terrain and environmental disturbances and socio-economic impacts of these proposed pipelines which are being discussed in detail in this Inquiry.

I will not go into the economic viability of either of these (CAGPL and Foothills) proposed pipeline systems, except to say that both companies have inherent in their applications the necessity of continuing explorations off-shore into the Beaufort Sea. Direct evidence submitted by R. Horsfield (overview, Delta Producers) and V. Horte (policy statement, CAGPL, phase one) indicates that the favourable potential for hydrocarbons in the Beaufort Sea is an important aspect of industry's presence in the Mackenzie Basin. The Mackenzie Basin does not stop at the shoreline, in fact a full three-quarters of it lies off-shore under the shallow waters of the Beaufort Sea. The surface conditions, i.e. land and water distribution have no relationship to the underlying geology, but in terms of practical exploitation of these resources the shoreline is a very significant boundary. The network of buried trunk pipelines, above ground feeder lines, gas plants and exploration drilling can be expected to expand well beyond that shown in figure 5.

Figure 6 shows a map of possible drill hole locations both onshore and offshore, in sufficient spacing to locate the major producing fields. This map is an estimate with some of the oil and gas finds shown to coincide with a large fault (Kaltag) running northeast from Shingle Point. The number of fields shown on this map represent some 30

tcf of gas and two or three billion barrels of oil. This is not an unreasonable estimate when using the discoveries on Richards Island from which to extrapolate. In any case this estimate of reserves is still somewhat less than believed to exist by industry. The drilling and ancillary systems shown later in Figure 7, then, are even less than would be necessary if higher reserves were discovered. This exploration and development will probably take place within the next 20 to 30 years.

The number of drill holes needed to sufficiently explore a given area is primarily dependent upon the size of the geological structures that are thought to contain hydrocarbons. In this respect the structures encountered so far in the Mackenzie Delta area have been relatively small (compared with Prudhoe Bay, for example). In fact the drilling record to date has been high enough with close enough spacing to virtually eliminate the possibility of a Prudhoe Bay size structure in the onshore areas.

There is some debate as to the nature and size of the structures existing in the offshore areas. In some cases seismic data seem to show less evidence of normal faulting and consequent splitting up of potential hydrocarbon bearing horizons into smaller segments. If the number of exploratory wells to be drilled offshore is estimated by extrapolating from the number of about 100 already drilled and the areas they covered, some 300 to 400 exploratory

holes have yet to be drilled offshore. If some credibility is given to the fact that some of the structures to be encountered offshore may be large, one might then say that 200 to 300 exploratory holes remain to be drilled in the area of the Beaufort Sea with water depths greater than ten metres.

With this drilling taking place in the summer months only (July to September), when the polar pack has receded some 50 to 100 miles from the coast, the question of drilling relief wells and oil cleanup in the event of a blowout becomes a serious problem. This will be dealt with in more detail in later panels. Let it suffice to say here, that nowhere else in the world is petroleum exploration carried out in such hostile environments.

Figure 7 is a composite of all permanent facilities that will have to exist if the oil and gas from the offshore is to be transported to the south. In Figure 5 we saw the gas plants to be constructed at Parson's Lake, Taglu and Niglintgak which are proposed to handle a throughput of initially some 1.25 bcf per day of gas. The trunk and lateral pipeline sizes for both Foothills and Canadian Arctic Gas imply much higher throughputs, in the three to four bcf per day range from the Delta area alone. This fact as well is an indication of the expected potential from the offshore areas. Horte in his direct evidence

(policy, phase one), has even talked of looping the primary line if enough proven reserves are located.

Figure 7 is a possible future scenario presenting a trunk gas pipeline, a looped gas line, a trunk oil line, above ground on-land oil and gas feeder lines, buried offshore oil and gas feeder lines with associated gas processing plants at King Point, Taglu, Parsons Lake and Tuktoyaktuk.

It is the consequences of this future development resulting from exploitation of the petroleum resources in the Mackenzie Beaufort Basin which concerns us at this point. In particular, as projects are considered one at a time it is important for each project evaluation to consider the effect of that project as part of a cumulative series of changes.

To date, specific applications for 1) gas plants at Taglu, Niglintgak and Parsons Lake, 2) trunk gas pipelines from the Mackenzie Delta up the Mackenzie River, and 3) flow lines or feeder lines from the various clusters to the corresponding gas plants have been made. The location of future plants and tank farms can only be estimated now and will eventually be defined by the location of the offshore fields. Depending on their locations, fairly lengthy offshore and onshore flowlines may have to be constructed. It is much more expensive to construct offshore flowlines,

therefore the shortest distance to shore is the one most likely to be chosen.

The two most important aspects of petroleum development moving into the Beaufort Sea are the problems encountered in drilling offshore and the transportation of the discovered hydrocarbons to land-based processing facilities. A number of problems have already been encountered in routine drilling in the Delta. These are 1) fires from loss of control of surface hydrates, 2) melting of permafrost and 3) cases of high geopressures. These problems must be dealt with even more rigorously when drilling offshore because of the obvious difficulty in the scope of contingency plans for their control.

Let us for a minute discuss the consequences of offshore production in terms of the needed flowlines. Depending upon the nature of the hydrocarbon deposits discovered, one might have a pool either mostly of gas, oil and gas, or mostly oil with dissolved gas. In any case these products must be brought to shore before, in the case of oil with dissolved gas, the separation of gas from the oil can be undertaken. This is necessitated by the fact that floating ice with keels scouring into the bottom at water depths of 100 feet or more prevent the use of platforms or subsea processing units as in the North Sea and Gulf of Mexico respectively. Observations of

keels digging up to 25 feet into the bottom have been noted, although the exact time in the past when this happened is not known. To be safe, one will probably have to bury the well to flowline hookup and the flowline itself some 30 feet below the bottom. As we are dealing here with unprocessed hot gas and or oil the flowline to shore will have to be kept hot (hot-wired) to prevent the formation of "slug flow" and hydrates from the gas and higher viscosity in the oil. This burial of flowlines and the necessity of them being kept hot creates a problem if the flowline encounters offshore permafrost. Sections of the sub-bottom material in large areas of the Beaufort Sea east of Mackenzie Bay have been found to be frozen. In some cases frozen soils seem to be very close to the surface. At this point, it is not known if these zones can be avoided, and if not, how much segregated and ground ice exists. If in fact these offshore flowlines must pass through frozen ground, it would be important to preserve the pre-existing thermal regime as much as possible, in order to prevent subsidence from damaging the flowlines. Thus must be done by wrapping the already insulated hot wired line with a refrigeration coil.

It is presumed that exploration drilling and subsea production clusters can be constructed in the same manner as on land, except for the fact that the well heads and

necessary hookups will have to be buried some 30 feet below the sea bottom. There will be a tendency to locate the future gas processing plants and oil tank farms in areas where development has already taken place, if possible, such as Taglu, Parsons Lake and Tuktoyaktuk. Depending on where oil is first found in significant quantities, tank farms will be constructed at the closest developed onshore facility. This will probably be the take-off point for an above ground hot oil pipeline. As development proceeds (as in figure 7) oil trunk pipeline tie-ins will be constructed. This map shows the oil trunk pipeline following the same right of way as the trunk gas pipelines, but this will probably not be the case, at least for the whole route.

Figure 7, then, is thought to be a reasonable scenario of future activities in the Mackenzie Delta - Beaufort Sea area. Figure 8 shows the distribution of oil and gas fields in the Williston Basin of Alberta, which has been developed over the last thirty years into a mature basin. The oil and gas fields and interconnecting pipelines form a complex system defined by geology and land leasing arrangements. It is not unreasonable to expect something of similar complexity in the Mackenzie Basin, although some cooperation is occurring among participant companies because of the high cost of exploration and development in frontier areas.

Recent evidence presented by Shell Canada indicates that they are now planning to construct their own gas processing plant at Niglintgak and that production will come from 9 or 10 separate wells and not a production cluster. This development scenario differs very little from initial developments in Alberta. Referring to figure 7 for a minute it is conceivable that the field recently delineated at Kumak will be tied into the gas plant at Niglintgak or Taglu. This will necessitate another above ground flow line.

In the southwestern Delta north of Aklavik Shell has recently carried out some rather detailed seismic work and if this in fact culminates in the discovery of a few small fields, further flow lines across the modern Delta to the Niglintgak plant will have to be constructed. Another area to be investigated further before abandonment will be the area bordering the east channel of the Mackenzie. From a geological point of view this area contains few structures but may contain petroleum in stratigraphic traps. If again some discoveries are made here, i.e. north and south of the east channel one could expect flow lines to the Taglu and Parsons processing plants respectively. This kind of fragmented, sporadic addition of small fields to the production network will eventually necessitate the complex criss-crossing of flow lines. If this development scenario is carried offshore it is not difficult to imagine the intricate nature of

flow lines that may exist. If one could locate all producing fields before constructing flow or feeder lines the interconnections could be made much more efficiently between fields. The offshore scenario presented in figure 7 is that of the most efficient flow network. If in fact some of the furthest offshore fields are discovered first and brought into production as soon as possible, then the closer to shore fields discovered after will necessitate separate flow lines.

Figure 9 shows the development to date in the Niger River Delta where some 1000 exploratory holes have been drilled and some 90 separate fields have been discovered. The scenario for the Mackenzie Delta may not resemble this in detail, but will surely have a complex character of its own. In actual size the Mackenzie-Beaufort area covers about half that of the Niger Delta, so that one may expect a somewhat proportional reduction in the necessary number of exploratory wells and the number of discovered fields. Obvious differences in the nature of the geological structures preclude any detailed extrapolation or comparison.

It is apparent that with further exploration of the remainder of the Mackenzie - Beaufort Basin, a complex and intricate network of petroleum related facilities will be constructed throughout the area.

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BORN: August, 1940

CITIZENSHIP: Canadian

EDUCATION: B.Sc., 1963, Geology and Mathematics, Carleton University, Ottawa, Ontario.
B.Sc., 1964, Hon. Geology, Carleton University, Ottawa, Ontario.
M.Sc., 1973, Marine Geology, Memorial University, St. John's, Newfoundland.
Thesis: Detailed Grain-size Analysis and Post-Glacial History of Port au Port Bay, West Newfoundland.
Ph.D., Marine and Glacial Geology, Dalhousie University, Halifax, Nova Scotia, incomplete.

WORK EXPERIENCE:

February 1975 to Present - Environmental Consultant with the Northern Assessment Group (Canadian Arctic Resources Committee) providing technical (permafrost conditions and surficial geology along proposed pipeline route) assistance to the native groups intervening in the Berger Hearings in Yellowknife. A scenario of possible future petroleum activity and development in the Mackenzie delta was also undertaken.

April 1974 to January 1975 - Geological Survey of Canada, Department of Energy, Mines and Resources, physical environmental studies for the Beaufort Sea project. Chief Scientist on PANDORA; using high resolution profiler, boomer, side-scan sonar, piston coring. Bottom examination from PISCES IV submersible. Comprehensive review of scour problem. (*Beaufort Sea project*)

January 1973 to March 1974 - Private Consultant with Hunttec (70) Ltd., Toronto, Ontario: working on M/V CROSBIE investigating marine pipeline routes for the Polar Gas Project. Investigation of permafrost and ice scour problems. Interpretation of all marine seismic data for Hunttec (70) for Montreal Engineering Ltd.

October 1970 to June 1973 - Terrain Sciences Division, Geological Survey of Canada, Department of Energy, Mines and Resources. Carried out a unique research program in the Western Canadian Arctic collecting baseline information for an

Arctic continental shelf, consisting of Mackenzie
Delta sedimentation, permafrost, marine pingos, seabed
scouring from keels of pressure ridges, sea level
transgression, geological history. Shallow seismic,
low frequency echo sounder and side-scan sonar techniques
used along with piston coring and bottom sampling.

May 1969 to September 1970 - Bedford Institute of Oceanography, Department
of Energy, Mines and Resources. Beach erosion studies
and assisted in shallow seismic study of Grand Banks of
Newfoundland. Ran a seismic reflection survey of
Northern Gulf of St. Lawrence.

1965 - 1969 Graduate Student: (marine geology and sedimentology),
bottom sampling, dissolved O₂, surficial geological
shoreline mapping, SCUBA diving in Port au Port Bay.
One year at Dalhousie in Ph.D. level studies.

1964 - 1965 Geological Survey of Canada: hammer seismic and seismic
refraction studies. Bottom sampling and coring from
HUDSON in Hudson Bay.

1959 - 1963 Undergraduate Student: hard rock mineral exploration
during summers in Central Newfoundland.

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Lyll, A. and Shearer, J. M. 1970. Recognizing fossil sand lines from grain-size analysis: comment on a paper by John Chappell. Department of Geology, Dalhousie University, Halifax, Nova Scotia. — *Journal of Sedimentary Petrology*, v. 39, pp. 1154-1155.

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FIGURE 1



FIGURE 2



FIGURE 3



FIGURE 4



FIGURE 5



FIGURE 6



FIGURE 9

